REMARKS/ARGUMENTS

Applicant would like to thank the Examiner for the careful consideration given the present application. The application has been carefully reviewed in light of the Office action, and amended as necessary to more clearly and particularly describe the subject matter, which applicant regards as the invention.

Applicant acknowledges with appreciation the indicated allowability of original claim 7 if rewritten to overcome the rejections under 35 U.S.C. 112, first and second paragraphs, set forth in the Office action and to include all of the limitations of the base claim and any intervening claims. Claim 7 has been amended and rewritten as claim 13 to overcome the rejections under 35 U.S.C. 112, first and second paragraphs. However, it is believed that new claim 11, upon which claim 13 depends, is allowable for the reasons discussed herein. Applicant reserves the right to cast claim 13 into independent form at a later date, if necessary.

Claim 4 was objected to as being of improper dependent form for failing to further limit the subject matter of the previous claim. Claim 4 has been canceled herein.

Claims 5-7 were rejected under 35 U.S.C. 112, first paragraph, for failing to enable a person skilled in the art to make/use the invention commensurate in scope with the claims. In particular, the Examiner states that while the specification is enabling for a textile cleaning apparatus with either an evaporator separate from the treatment chamber or an evaporator as part of the treatment chamber, the specification does not reasonably provide enablement for a textile cleaning apparatus with both types of evaporators. Accordingly, claim 5 has been canceled and rewritten in independent form as new claim 11 to include only the alternative of the textile cleaning apparatus with the evaporator as part of the treatment chamber.

Regarding claim 7, the Examiner stated that while being enabling for a heat exchanger (82), the specification does not reasonably provide enablement for a "tube (82)". Accordingly, claim 7 has been amended and rewritten as claim 13 to replace "tube" with "heat exchanger".

Claims 1-7 were rejected under 35 U.S.C. 112, second paragraph, as being indefinite. Claims 1-7 have been canceled herein. New claims 8-13 have been added to cure the 112, second paragraph, issues in accordance with the Examiner's suggestions.

Claims 1-3 were rejected under 35 U.S.C. 102(e) as being anticipated by US 5,904,737 to

Preston et al. Traversal of this rejection is made for at least the following reasons. As stated above, claims 1-3 were rewritten herein as claims 8-10 and thus will be referenced as claims 8-10 for the purposes of simplicity. Preston et al. does not disclose a *condenser in heat transferring contact with the evaporator chamber*, as recited in claim 8. The Examiner contends that tank 18 of Preston et al. is equivalent to the claimed condenser. Applicants respectfully disagree. Tank 18 is merely employed to store liquid carbon dioxide. In fact, storage tank 18 is substantially equivalent in function to storage tank 20, which the Examiner relies upon as being equivalent to the claimed supply tank. Accordingly, although storage tank 18 is in heat transferring contact with still 70, which is relied upon by the Examiner as being equivalent to the claimed evaporator chamber, the storage tank 18 is not a condenser. In contrast, Preston et al. discloses that transfer tank 12 is employed to condense carbon dioxide gas into liquid carbon dioxide. See col. 3, lines 33-35 and col. 6, lines 13-15. The transfer tank 12 is not in heat transferring contact with the still 70.

Moreover, Preston et al. does not disclose wherein *the compressor and the condenser form a heat pump* which alone provides energy required for evaporation of liquid in the evaporator chamber, as recited in claim 8. Rather, as storage tanks 18 and 20 cycle through an agitation process, the pressure and temperature of storage tank 18 rises such that the warmer temperature of the liquid carbon surrounding the still 70 causes the liquid carbon dioxide therein to boil and vaporize. The vaporized carbon dioxide then flows to transfer tank 12 where it is condensed. The transfer tank 12, which acts as the condenser, does not act with compressor 14 to form a heat pump that, alone, provides energy for vaporization of the liquid carbon dioxide within the still 70.

Because Preston et al. does not disclose each and every limitation set forth in claim 8, Preston et al. does not anticipate such claim. Withdrawal of this rejection is respectfully requested.

Claims 1-3 and 5-6 were rejected under 35 U.S.C. 102(e) as being anticipated by US 5,946,945 to Kegler et al. Traversal of this rejection is made for at least the following reasons. Again, claims 1-3 and 5-6 were rewritten herein as claims 8-10 and 11-12, respectively, and will be referred to as such for simplicity. Kegler et al. does not disclose a compressor and a

condenser forming a heat pump which alone provides energy required for evaporation of liquid in the evaporator, as required by independent claims 8 and 11. Kegler et al. merely states that liquid carbon dioxide is cycled from the cleaning vessel 11 to the solvent recovery device 12, which functions to vaporize the liquid carbon dioxide. The gaseous carbon dioxide is then directed to a condenser where it is reliquified and returned to the storage tank 15. Kegler et al. does not disclose that the condenser and compressor 14 act to form a heat pump. Moreover, detail regarding what is employed to provide energy for evaporation of the liquid carbon dioxide is absent from Kegler et al.

Further, Kegler et al. does not disclose a treatment chamber having an evaporator therein, as recited in claim 11. Rather, in Kegler et al., liquid carbon dioxide is vaporized in solvent recovery device 11, which is located outside and apart from the treatment chamber, or cleaning vessel 11.

Because Kegler et al. does not disclose each and every element set forth in claims 8 and 11, Kegler et al. does not anticipate such claims. Withdrawal of this rejection is respectfully requested.

In light of the foregoing, it is respectfully submitted that the present application is in a condition for allowance and notice to that effect is hereby requested. If it is determined that the application is not in a condition for allowance, the Examiner is invited to initiate a telephone interview with the undersigned attorney to expedite prosecution of the present application.

If there are any additional fees resulting from this communication, please charge same to our Deposit Account No. 16-0820, our Order No. 33897.

Respectfully submitted,

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TITLE: APPARATUS FOR CLEANING TEXTILES WITH A DENSIFIED LIQUID TREATMENT GAS

FIELD OF THE INVENTION

The present invention relates to an apparatus for cleaning textile objects using a densified, liquid treatment gas, which preferably, is constituted by carbon dioxide.

BACKGROUND OF THE INVENTION

By washing textile objects, one has traditionally had the possibility to choose to treat these in a detergent solution based on water, or to utilize a dry cleaning method, where water is replaced by trichlorethene or perchlorethene. By what is known as common wash, which can be used for most articles of clothing, garments are placed in a treatment drum of a washing machine to be cleaned in a detergent solution based on water. For garments not washed in water, the garments are instead placed in a dry-cleaning machine and are cleaned in a wash-solution based on solvents, usually containing perchlorethene. Those solutions based on solvents have, from an environmental standpoint, been found to be inappropriate, and hence one has tried to find replacement liquids, which from a washing viewpoint are equally good as wash-solutions based on solvents earlier used, but which at the same time do not demonstrate the drawbacks from an environmental viewpoint, which are inherent in the wash-solutions based on solvents.

Such a replacement liquid having suitable properties for cleaning of textiles is carbon dioxide in liquid or supercritical state. The patent specification US-A-5,267,455 describes a system for chemically cleaning textiles using carbon dioxide in liquid or supercritical state. This system include a treatment chamber, a supply tank for liquid carbon dioxide and likewise a vaporization chamber for liquid carbon dioxide, which has been used in the process and shall after purification be brought back to the supply tank. The liquid carbon dioxide is pumped from the supply tank to the treatment chamber, and when the cleaning process has been completed, from the treatment chamber to the vaporization chamber. The vaporization of the liquid carbon dioxide takes place by heating, and the evaporated gas is conveyed through filters and a condensing apparatus back to the supply tank. The described process depicts how the chemical cleaning using liquid carbon dioxide should possibly come about, but is by no way optimized with respect to recovering from treatment and vaporization

chambers liquid and gaseous carbon dioxide respectively. Because of the existing pressure conditions in the supply tank and in the vaporization chamber one cannot completely empty the vaporization chamber of gas, without specific measures. The solution will be to evacuate surplus gas to the ambient air, which entails that this gas must be replaced from a gas supplier, and that to a cost which is not negligible.

WO 99/13 148 describes a device for cleaning garments in liquid carbon dioxide. Like the apparatus of US patent 5,267,455, WO 99/13 148 describes a device comprising a treatment chamber, a supply tank and a vaporization chamber, which are mutually connected to each other by way of suitable tubes and valve means. Further, the device comprises compressor means, which is used partly, most important, to completely empty the treatment chamber of carbon dioxide, partly to serve as driving means for carbon dioxide gas, which during one in treatment process included vaporization process from the vaporizer via condenser means shall be brought back to the supply tank. To evaporate liquid carbon dioxide in the vaporizer there are arranged particular heating means, and further, the condensing of carbon dioxide gas, which via the compressor means is directed to the condensation means, takes place without taking care of the energy thereby released.

Thus one object of the present invention is to improve the device for cleaning textiles mentioned as known, as far as possible all in the system circulating carbon dioxide being taken care of, and after cleansing being brought back to the supply tank. Another object is to take care of the energy released during the process, and utilize this in process steps, where otherwise energy provided from outside has to be utilized.

SUMMARY OF THE INVENTION

The stated objects will be obtained by a device for cleaning textiles with densified, liquid state treatment gas.

DETAILED DESCRIPTION OF THE INVENTION

The invention will herein be described in detail with reference to embodiments shown on the drawing, in which figure 1, schematically, shows a first embodiment of a device, according to the invention, intended for cleaning textiles in a washing fluid consisting of liquid carbon dioxide. Figure 2 shows a modified embodiment of the device according to figure 1.

With reference to figure 1, the device comprises, expressed in common language, a washing machine, a treatment chamber 10, in which the textiles to be cleaned are introduced. The treatment chamber 10 is of heavy duty accomplishment to be able to resist the high pressures, which are required to keep the carbon dioxide in fluid state at a temperature in the main corresponding to room temperature. A door 12 is arranged to seal the chamber 10, and also this is in the same solid accomplishment. Suitable locking means, not shown, are arranged in order to keep the door 12 in a locked position during the cleaning operation in the treatment chamber 10.

To get the cleaning of the textiles in the treatment chamber as effective as possible, an agitation of those is desired, and for that object the textiles are supported in an interior of a revolving washing drum 14 inside the treatment chamber 10. In prevalent way the drum may be equipped with carry-over bulges, not shown, intended to lift the textiles from the bottom of the drum during its revolving, and again release these as they have reached the upper part of the drum. In this way different parts of the textiles are brought in contact with the liquid carbon dioxide in a more uniform way. The revolving driving of the drum can be brought about with the aid of an electric motor 16, by way of a suitable transmission, for example in the way described in the patent US-A-5,267,455.

For supply of the liquid carbon dioxide, there is arranged a supply tank 18, the lower part of which is through tubes 20, 22 and valve 24 connected with the lower part of the treatment chamber 10. The upper part of the supply tank 18 is through tubes 26, 28, 30 and 32 along with valves 29, 33, 34 connected with the upper part of the treatment chamber 10.

For recycling of the carbon dioxide used in the cleaning process, there is arranged ~~a~~ an evaporator chamber 36, which through tubes 38, 40 with intermediate valve 42 is connected to the treatment chamber 10 at its lowermost part. For vaporization of the liquid carbon dioxide, which is conveyed from the treatment chamber 10 through the tubes 38, 40 and the valve 42 to the evaporator chamber 36, a heat exchanger in form of a condenser 44 is used.

A compressor 46 is a vital component in the washing machine according to the invention, and this compressor is driven by an electric motor 48. The compressor is used in substance to completely empty the treatment chamber 10 and the evaporator chamber 36 after the cleaning and vaporization processes are finished, respectively. The pressure side of the compressor 46 is connected to an inlet to the heat exchanger

44 through tubes 50, 52 and an intermediate valve 54, and the outlet of the lower most part of the exchanger 44 is connected to the supply tank 18 through tubes 56, 58 and 60, an additional heat exchanger 62 and a valve 64. The low side of the compressor is connected to the tube 28 through a tube 66.

A valve 69 is arranged to evacuate air from the treatment chamber 10 before this will be filled with carbon dioxide. To compensate carbon dioxide lost during a preceding treatment phase, a further valve 68 is arranged to permit filling of the treatment chamber with new carbon dioxide, before a new treatment phase is begun. Carbon dioxide can, for instance, be partly left in the articles of clothing, and partly be evacuated to the ambient air.

The action of the washing machine shown in figure 1 will now be described. Upon introduction of articles of clothing in the washing drum 14 in the treatment chamber 10 of the machine, the door 12 will be closed and locked in a non specified manner. After this moment, the treatment chamber will be evacuated of air, which takes place through the opening of the valve 69 and a pump 67 is actuated and works until the pressure is about 5.5 bar. When a pressure sensor 70 has detected this pressure in the treatment chamber 10, the valve 69 is closed and the pump 67 stopped. The next step is represented by a pre-pressurization of the treatment chamber 10, i.e. a connecting path is established from the supply tank 18 to the treatment chamber 10 in such a way that the pressure in the treatment chamber 10 attains a level of approximately 10 bar. The connection path is formed by the tube 26, the valves 29 and 33, the tube 30, the valve 34 and a tube 32. When the new pressure level has been attained in the treatment chamber 10, the valve 34 is closed and a valve 68 is opened for feeding new carbon dioxide to the treatment chamber 10 from an external supply, i.e. gas tube furnished by a gas deliverer. The duty of this additional carbon dioxide is to compensate for carbon dioxide, which was lost during the previous treatment phase of the washing machine. For this purpose, the valve 68 is held open during a suitable time, and will be closed thereupon.

After refilling of new carbon dioxide to the system, liquid carbon dioxide should be fed to the treatment chamber 10 from the supply tank 18. This phase starts with pressure balancing between the gas-side of the supply tank 18, i.e. the uppermost part of the supply tank, and the treatment chamber 10, and for this purpose, the valve 34 will be opened. The valves 29 and 33 are already open. When the pressures in the treatment chamber 10 and in the supply tank 18 are equalized, the valve 24 will open

and liquid carbon dioxide will flow through the tube 20, the valve 24 and the tube 22 into the treatment chamber 10 up to a predetermined level. The amount of transferred carbon dioxide can easily be determined through measuring the lowering in level in the supply tank 18. By placing the supply tank 18 on a higher level than the treatment chamber 10, the transfer of liquid carbon dioxide from the supply tank to the treatment chamber can take place due to influence of gravitation thereby dispensing of the need for a pump.

When the filling of the treatment chamber has been completed, all valves are closed and the cleaning process in the treatment chamber can commence. This process proceeds for roughly 10 minutes. Shortly afterwards, the drum 14, with its load of garments, rotates in the liquid carbon dioxide, and during the rotation, treats and performs a stirring of the articles of clothing, so as to give the washing liquid, the liquid carbon dioxide, good exposure to all parts of the garments.

When the cleaning process has been finished, the washing liquid in the treatment chamber 10 shall be removed and the pressure therein lowered to atmospheric pressure, so that the door 12 can be opened and the clean garments can be removed from the treatment chamber. The liquid carbon dioxide in the treatment chamber 10 will be taken care of in such a way that it is conveyed to the evaporator chamber 36 to be vaporized and from there, be brought back to the supply tank 18 via a condenser or heat exchanger 44. As in this stage the pressure differs very much between the evaporator chamber 36, the supply tank 18 and the treatment chamber 10, one should increase the pressure in the evaporator chamber 36 step by step through pressure balancing, first with the supply tank 18, and thereupon with the treatment chamber 10, which in this stage has the highest pressure, and from where the liquid carbon dioxide shall also be conveyed to the evaporator chamber 36. In a first step, a connection is established between the supply tank 18 and the evaporator chamber via the tube 26, the valves 29 and 33, the tube 30, another tube 31, a valve 27 and a tube 35 in order to increase the pressure in the evaporator chamber 36 to about the same level as that existing in the supply tank 18. Subsequently the valves 29 and 33 are closed.

In a second step, pressure balancing shall take place between the treatment chamber 10 and the evaporator chamber 36, and for this purpose, the valve 34 will be opened to establish a connection between the treatment chamber 10 and the evaporator chamber 36 through the tube 32, the valve 34, the tube 31, the valve 27

and the tube 35. When the pressures are equal in the treatment chamber 10 and the evaporator chamber 36, a valve 42 is opened so that a connection is opened between the lower part of the treatment chamber 10 and the evaporator chamber 36 via the tube 38, the valve 42 and the tube 40. The valve 42 is kept open as long as required for all free liquid carbon dioxide in the treatment chamber 10 to leave for the evaporator chamber 36. If the treatment chamber 10 is located above the evaporator chamber 36, the transfer of liquid carbon dioxide from the treatment chamber to the evaporator chamber can take place by means of gravitation. Otherwise, a pump will be necessary to transfer the liquid carbon dioxide.

The evaporator chamber 36 now contains dirt-mingled washing liquid and liquid carbon dioxide from the treatment chamber 10, and in its upper part, gaseous carbon dioxide. To separate the dirt from the liquid carbon dioxide, a process of distillation will follow, where gaseous carbon dioxide, with aid of the compressor 46, will be sucked from the evaporator chamber 36, through the condenser or heat exchanger 44, and conveyed to the supply tank 18, where the carbon dioxide again reaches its liquid state. Now the valve 42 closes and the valves 33 and 54 open while the valve 64 and a valve 65 are activated to regulate the pressure in the tube upstream the valves and compensate for the pressure in the compressor 46 and in the supply tank 18. The compressor 46 is started and is allowed to run until the pressure in the evaporator chamber tends to decrease. The compressor sucks gaseous carbon dioxide from the evaporator chamber 36 through the tube 35, the valve 27, the tube 31, the tube 30, the valve 33 and the tube 66 and gives off gaseous carbon dioxide at enhanced pressure and heat content through the tube 50, the valve 54, the tube 52 to the heat exchanger 44, where heat is emitted to the evaporator chamber 36 under condensation of the gaseous carbon dioxide. In this phase, the gas is essentially condensed and can be conveyed through the tube 56 to a further heat exchanger 62, the task of which is to completely condense the remaining gaseous carbon dioxide in order to convey only liquid carbon dioxide back to the supply tank 18 via the tube 58, the valves 64 and 65 and the tube 60.

When the distillation process has been finished, preparations for opening the door 12 and taking out of the clean articles of clothing follow ~~on~~. For this purpose, first the pressure in the treatment chamber 10 has to be decreased and should assume the value 1.5 bar. Thus the valve 33 will be closed while valve 55 is opened and the compressor 46 is started and can work until the pressure in the treatment chamber 10

has assumed the desired value of 1.5 bar. To make it possible to open the door 12, the pressure in the treatment chamber must be decreased further to the value 0 bar, and for this purpose a so called free-blowing takes place, which is brought about by opening a valve 39, and via a filtering device 41, conveying the remaining gaseous carbon dioxide to the ambient air.

Before the door is opened, the distillate is taken care of, i.e. the dirt segregated in the evaporator chamber 36. This is called dirt-blowing and implies that a valve 43 is rapidly opened and closed to press out the distillate and at the same time minimize the amount of gaseous carbon dioxide accompanying the distillate. After this operation, the cleaning process is completed, and the door 12 can be opened for taking out the clean articles of clothing.

Prior to a new washing process, the balance in the supply tank 18 may need adjustments in respect of temperature and pressure. For this purpose, the valves 55, 64 and 65 are opened and the compressor 46 will be started and allowed to run until the pressure in the supply tank 18 assumes a suitable value, for example, 57 bar. If required, the heat exchanger 62 is also activated. Afterwards, all valves are closed and the compressor 46 will be stopped.

For control of the function of the washing machine, preferably, a computerized guide system is provided which receives information on pressure and temperature states in the treatment chamber 10, the supply tank 18 and likewise in the evaporator chamber 36 from suitable temperature and pressure sensors therein. Moreover, it is of value to be able to measure the level of liquid carbon dioxide in the supply tank 18 and in the treatment chamber 10, and to this end, suitable level gauges can be provided. The different sensors for pressure, temperature and level are schematically shown on the drawing, but are not described in detail since they are of conventional designs, and have no specific significance in connection with the invention. The same is valid for the chosen computerized control system, which in the same way can be of any conventional kind.

As evident from the above given description of a preferred embodiment of the invention, the gaseous carbon dioxide in the described washing machine is taken care of practically completely. Due to connections between different parts in the machine, a necessary pressure balancing takes place between containers holding vaporized carbon dioxide, the treatment chamber 10, and the evaporator chamber 36. The pressure balancing takes place before transferring liquid carbon dioxide from the

supply tank 18 to the treatment chamber 10 and from the treatment chamber 10 to the evaporator chamber 36, respectively. In relation to the distillation of gaseous carbon dioxide from the evaporator chamber 36, condensing takes place in the condenser or heat exchanger 44 of gaseous carbon dioxide released from the compressor 46 under raised pressure and increased heat content. Heat given off is then utilized to vaporize the liquid carbon dioxide in the evaporator chamber 36. Thus, in this way, one can dispense with specific heating arrangements for the evaporation process.

In the embodiment shown in figure 1, a separate vaporizer is arranged. To further simplify the washing machine, in a modified embodiment as shown in figure 2, the evaporator chamber 36 is excluded, and the vaporization of liquid carbon dioxide takes place directly from the treatment chamber 10. In the schematically shown example of figure 2, the vaporizer has been depicted as a box designated 80, which is located beneath the treatment chamber 10 and contains a heat exchanger 82 of a kind similar to the heat exchanger 44 in figure 1.

The function of the device shown in figure 2 is essentially the same as the one by the device according to figure 1. Owing to that, the vaporization in this embodiment takes place directly from the treatment chamber 10 instead of from a separate evaporator 36. Accordingly, the process steps in the embodiment according to figure 1, which relates to the transfer of liquid carbon dioxide from the treatment chamber to the evaporator chamber, as well as some of the necessary pressure balancing moments between the evaporator chamber, the treatment chamber and the supply tank can be dispensed with.

During the condensing progress, the task in both embodiments according to figure 1 and figure 2 is to empty the treatment chamber of liquid carbon dioxide, and, at the same time, clean the working fluid from impurities having been released from textiles processed in the treatment chamber. In the washing machine according to figure 2 the evaporation process, which continues as the treatment phase has been concluded, in brevity takes place in the following manner.

The valves 33, 54 and 64 are opened and the compressor started so that gaseous carbon dioxide is sucked from the treatment chamber 10 through the tubes 32 and 30, the valve 33 and the tube 66. The compressor 46 delivers gaseous carbon dioxide with raised pressure and increased temperature, and gas is conveyed through the tube 50, the valve 54 and the tube 52 to the heat exchanger 82, where it gives off its heat. The carbon dioxide, essentially in liquid state, is conveyed further on via the

tube 56 to the heat exchanger 62, where possibly remaining gaseous carbon dioxide is transferred to liquid state. The liquid carbon dioxide is, after that, conveyed through the tube 58, the valve 64 and the tube 60 back to the supply tank 18. Thanks to the evaporator chamber, now constituting a part of the treatment chamber 10, and the heat exchanger 82, to its function as a condenser, the gaseous carbon dioxide is provided in direct connection to the treatment chamber and emits condensing heat to that, at the embodiment according to figure 2, an advantageous simplification of the washing machine is obtained. As in the embodiment of figure 1, by means of the action of the compressor 46, the working fluid, i.e. carbon dioxide in liquid and gaseous state, as a whole, is completely taken care of by the compressor. Owing to that, the heat released by condensing the carbon dioxide is brought back to the process, the amount of energy needed from outside is restricted, and specific heating devices for evaporation of liquid carbon dioxide can be dispensed with. This also entails that every treatment phase where textiles are cleaned in liquid carbon dioxide can be followed by a distilling phase, so that the liquid state carbon dioxide brought back to the supply tank is always clean. This is not the case in the above mentioned publication WO-99/13148, where during the cleaning process, the liquid carbon dioxide is circulated through filtering means and the supply chamber back to the treatment chamber, and is consequently not completely cleaned like at a distillation process. According to the invention, the problem has found its solution by way of the heat energy available in the evaporator, which has been changed up by a heat pump formed of the compressor means and the condenser means.

The invention is not restricted to the above described embodiment and in the shown drawings, but modifications and additions can be introduced within the concept of invention as defined in the following patent claims.

TITLE: APPARATUS FOR CLEANING TEXTILES WITH A DENSIFIED LIQUID TREATMENT GAS

FIELD OF THE INVENTION

The present invention ~~concerns~~ relates to an apparatus for cleaning textile objects using a densified, liquid treatment gas, which ~~preferebly~~ preferably, is constituted by carbon dioxide.

BACKGROUND OF THE INVENTION

By washing textile objects, one has traditionally had the possibility to choose to treat these in a detergent solution based on water, or to utilize a dry cleaning method, where water is replaced by trichlorethene or perchlorethene. By what is known as common wash, which can be used for most articles of clothing, ~~these~~ garments are placed in a treatment drum of a washing machine to be cleaned in a detergent solution based on water. For ~~garmets~~ garments not ~~standing water wash, those~~ washed in water, the garments are instead placed in a dry-cleaning machine and are cleaned in a wash-solution based on solvents, usually containing perchlorethene. Those solutions based on solvents ~~has~~ have, from an environmental standpoint, been found to be inappropriate, and hence one has tried to find replacement liquids, which from a washing viewpoint are equally good as wash-solutions based on solvents earlier used, but which at the same time do not demonstrate the ~~drawbacks from~~ drawbacks from an environmental ~~viewpoint which~~ viewpoint, which are inherent in the wash-solutions based on solvents.

Such a replacement liquid having suitable properties for cleaning of textiles is carbon dioxide in liquid or supercritical state. The patent specification US-A-5,267,455 describes a system for ~~chemicaly~~ chemically cleaning textiles using carbon dioxide in liquid or supercritical state. This system include a treatment chamber, a supply tank for liquid carbon dioxide and likewise a vaporization chamber for liquid carbon dioxide, which has been used in the process and shall after purification be brought back to the supply tank. The liquid carbon dioxide is pumped from the supply tank to the treatment chamber, and when the cleaning process has been completed, from the treatment chamber to the vaporization chamber. The vaporization of the liquid carbon dioxide takes place by heating, and the evaporated gas is conveyed through filters and a condensing apparatus back to the supply tank. The described

process depicts how the chemical cleaning using liquid carbon dioxide should possibly come about, but is by no way optimized with respect to recovering from treatment and vaporization chambers liquid and gaseous carbon dioxide respectively. Because of the existing pressure conditions in the supply tank and in the vaporization chamber one cannot completely empty the vaporization chamber of gas, without specific measures. The solution will be to evacuate surplus gas to the ambient air, which entails that this gas must be replaced from a gas supplier, and that to a cost which is not negligible.

~~The publication~~ WO 99/13 148 describes a device for cleaning ~~of garmets~~ garments in liquid carbon dioxide. Like ~~at~~ the apparatus of US patent 5,267,455, ~~this document~~ WO 99/13 148 describes a device comprising a treatment chamber, a supply tank and a vaporization chamber, which are mutually connected to each other by way of suitable tubes and valve means. Further, the device comprises compressor means, which is used partly, most important, to completely empty the treatment chamber of carbon dioxide, partly to serve as ~~drivng~~ driving means for carbon dioxide gas, which during one in treatment process included vaporization process from the vaporizer via condenser means shall be brought back to the supply tank. To evaporate liquid carbon dioxide in the vaporizer there are arranged particular heating means, and further, the condensing of carbon dioxide gas, which via the compressor means is directed to the condensation means, takes place without taking care of the energy thereby released.

Thus one object of the present invention is to improve the device for cleaning textiles mentioned as known, as far as possible all in the system circulating carbon dioxide being taken care of, and after cleansing being brought back to the supply tank. Another object is to take care of the energy released during the process, and utilize this in process steps, where otherwise energy provided from outside has to be utilized.

SUMMARY OF THE INVENTION

The stated objects will be obtained by a device for cleaning textiles with densified, liquid state treatment gas~~, which are given the characteristics stated in claim 1. Preferred embodiments are included in adherent sub-claims~~.

DETAILED DESCRIPTION OF THE INVENTION

The invention will ~~here~~ herein be described in detail with reference to embodiments shown on the drawing, in which figure 1, schematically, shows a first embodiment of a device, according to the invention, intended for cleaning textiles in a washing fluid consisting of liquid carbon dioxide. ~~, and figure~~ Figure 2 shows a modified embodiment of the device according to figure 1.

With reference to figure 1, the device comprises, expressed in common language, a washing machine, a treatment chamber 10, in which the textiles to be cleaned are introduced. The treatment chamber 10 is of heavy duty accomplishment to be able to resist the high pressures, which are required to keep the carbon dioxide in fluid state at a temperature in the main corresponding to room temperature. A door 12 is arranged to seal the chamber 10, and also this is in the same solid ~~accompishment~~ accomplishment. Suitable locking means, not shown, are arranged in order to keep the door 12 in a locked position during the cleaning operation in the treatment chamber 10.

To get the cleaning of the textiles in the treatment chamber as effective as possible, an agitation of those is desired, and for that object the textiles are supported in an interior of a revolving washing drum 14 inside the treatment chamber 10. In prevalent way the drum may be equipped with carry-over bulges, not shown, intended to lift the textiles from the bottom of the drum during its revolving, and again release these as they have reached the upper part of the drum. In this way different parts of the textiles are brought in contact with the liquid carbon dioxide in a more uniform way. The revolving driving of the drum can be brought about with the aid of an electric motor 16, by way of a suitable transmission, for example in the way described in the patent US-A-5,267,455.

For supply of the liquid carbon dioxide, there is arranged a supply tank 18, the lower part of which is through tubes 20, 22 and valve 24 connected with the lower part of the treatment chamber 10. The upper part of the supply tank 18 is through tubes 26, 28, 30 and 32 along with valves 29, 33, 34 connected with the upper part of the treatment chamber 10.

For recycling of the carbon dioxide used in the cleaning process, there is arranged ~~a~~ an evaporator chamber 36, which ~~trough~~ through tubes 38, 40 with intermediate valve 42 is connected to the treatment chamber 10 at its lowermost part. For vaporization of the liquid carbon dioxide, which is conveyed from the treatment

chamber 10 through the tubes 38, 40 and the valve 42 to the evaporator chamber 36, a heat exchanger in form of a condenser 44 is used.

A compressor 46 is a vital component in the washing machine according to the invention, and this compressor is driven by an electric motor 48. The compressor is used in substance to completely empty the treatment chamber 10 and the evaporator chamber 36 after ~~finished~~ the cleaning and ~~evaporization~~ vaporization ~~process respectivily~~ processes are finished, respectively. The pressure side of the compressor 46 is connected to an inlet to the heat exchanger 44 through tubes 50, 52 and an ~~intermidiate~~ intermediate valve 54, and the outlet of the lower most part of the exchanger 44 is connected to the supply tank 18 through tubes 56, 58 and 60, an additional heat exchanger 62 and a valve 64. The low side of the compressor is connected to the tube 28 through a tube 66.

A valve 69 is arranged to evacuate air from the treatment chamber 10 before this will be filled with carbon dioxide. To compensate carbon dioxide lost during a preceding treatment phase, a further valve 68 is arranged to permit filling of the treatment chamber with new carbon dioxide, before a new treatment phase is begun. Carbon dioxide can, for instance, be partly left in the ~~garmet~~ articles of clothing, and partly be evacuated to the ambient air.

The action of the washing machine shown in figure 1 will ~~here~~ now be described. Upon introduction of articles of clothing in the washing drum 14 in the treatment chamber 10 of the machine, the door 12 will be closed and locked in a non specified manner. After this moment, the treatment chamber will be evacuated of air, which takes place through the opening of the valve 69 and a pump 67 is actuated and works until the ~~pressure: 5 0.5~~ pressure is about 5.5 bar. When a pressure sensor 70 has detected this pressure in the treatment chamber 10, the valve 69 is closed and the pump 67 stopped. The next step is represented by a pre-pressurization of the treatment chamber 10, i.~~-~~e. a connecting path is established from the supply tank 18 to the treatment chamber 10 in such a way that the pressure in the treatment chamber 10 ~~attain~~ attains a level of approximately 10 bar. The connection path is formed by the tube 26, the valves 29 and 33, the tube 30, the valve 34 and a tube 32. When ~~in the treatment chamber 10~~ the new pressure level has been attained in the treatment chamber 10, the valve 34 is closed and a valve 68 is opened for feeding new carbon dioxide to the treatment chamber 10 from an external supply, i.~~-~~e. gas tube furnished by a gas deliverer. The duty of this additional carbon dioxide is to compensate for

carbon dioxide, which was lost during the previous treatment phase of the washing machine. For this purpose, the valve 68 is held open during a suitable time, and will be closed thereupon.

After refilling of new carbon dioxide to the system, liquid carbon dioxide should be fed to the treatment chamber 10 from the supply tank 18. This phase starts with pressure balancing between the gas-side of the supply tank 18, i.~~-e~~. the uppermost part of the supply tank, and the treatment chamber 10, and for this purpose, the valve 34 will be opened. The valves 29 and 33 are already open. When the pressures in the treatment chamber 10 and in the supply tank 18 are equalized, the valve 24 will ~~be opened~~ open and liquid carbon dioxide ~~flows~~ will flow through the tube 20, the valve 24 and the tube 22 into the treatment chamber 10 up to a predetermined level. The amount of transferred carbon dioxide can easily be determined through measuring the lowering in level in the supply tank 18. By placing the supply tank 18 on a higher level than the treatment chamber 10, the transfer of liquid carbon dioxide from the supply tank to the treatment chamber can take place due to influence of gravitation ~~so as to a pump can be despensed with~~ thereby dispensing of the need for a pump.

When the filling of the treatment chamber has been completed, all valves are closed and the cleaning process in the treatment chamber can commence. This process proceeds ~~during~~ for roughly 10 minutes ~~and implies shortly that~~. Shortly afterwards, the drum 14, with its load of ~~garmets~~ garments, rotates in the liquid carbon dioxide, and during the rotation, ~~it~~ treats and ~~perform~~ performs a stirring of the articles of clothing, so as to give the washing ~~liquor~~ liquid, the liquid carbon dioxide, good exposure to all parts of the ~~garmets~~ garments.

When the cleaning process has been finished, the washing ~~liquor~~ liquid in the treatment chamber 10 shall be removed and the pressure therein lowered to atmospheric pressure, so that the door 12 can be opened and the clean ~~garmets~~ garments can be removed from the treatment chamber. The liquid carbon dioxide in the treatment chamber 10 will be taken care of in such a way that it is conveyed to the evaporator chamber 36 to be vaporized and from there, ~~via a condenser or heat exchanger 44~~ be brought back to the supply tank 18 via a condenser or heat exchanger 44. As in this stage the pressure differs very much between the evaporator chamber 36, the supply tank 18 and the treatment chamber 10, one should increase the pressure in the evaporator chamber 36 step by step through pressure balancing, first with the

supply tank 18, and thereupon with the treatment chamber 10, which in this stage has the highest pressure, and from where ~~also~~ the liquid carbon dioxide shall also be conveyed to the evaporator chamber 36. In a first step, a connection is established between the supply tank 18 and the evaporator chamber via the tube 26, the valves 29 and 33, the tube 30, another tube 31, a valve 27 and a tube 35 in order to increase the pressure in the evaporator chamber 36 to about the same level as that existing in the supply tank 18. Subsequently the valves 29 and 33 are closed.

In a second step, pressure balancing shall take place between the treatment chamber 10 and the evaporator chamber 36, and for this purpose, the valve 34 will be opened to establish a connection between the treatment chamber 10 and the evaporator chamber 36 through the tube 32, the valve 34, the tube 31, the valve 27 and the tube 35. When the pressures are equal in the treatment chamber 10 and the evaporator chamber 36, a valve 42 is opened so that a connection is opened between the lower part of the treatment chamber 10 and the evaporator chamber 36 via the tube 38, the valve 42 and the tube 40. The valve 42 is kept open as long as required for all free liquid carbon dioxide in the treatment chamber 10 to leave for the evaporator chamber 36. ~~Depending on that~~ If the treatment chamber 10 is located above the evaporator chamber 36, the transfer of liquid carbon dioxide from the treatment chamber to the evaporator chamber can take place by means of gravitation~~, and an otherwise necessary pump can be despensed with~~. Otherwise, a pump will be necessary to transfer the liquid carbon dioxide.

The evaporator chamber 36 now contains dirt-mingled washing liquid and liquid carbon dioxide from the treatment chamber 10, and in its upper part, gaseous carbon dioxide. To separate the dirt from the liquid carbon dioxide, a process of ~~destillation~~ distillation will follow, where gaseous carbon dioxide, with aid of the compressor 46, will be sucked from the evaporator chamber 36, ~~and~~ through the condenser or heat exchanger 44, and ~~is~~ conveyed to the supply tank 18, ~~which~~ where the carbon dioxide again reaches ~~in~~ its liquid state. Now the valve 42 ~~being closed~~ closes and the valves 33 and 54 ~~are opened,~~ open while the valve 64 and a valve 65 are activated to regulate the pressure in the tube upstream the valves and compensate for the pressure in the compressor 46 and in the supply tank 18. The compressor 46 is started and is allowed to run until the pressure in the evaporator chamber tends to decrease. The compressor sucks gaseous carbon dioxide from the evaporator chamber 36 through the tube 35, the valve 27, the tube 31, the tube 30, the valve 33 and the

tube 66 and gives off gaseous carbon dioxide at enhanced pressure and heat content through the tube 50, the valve 54, the tube 52 to the heat exchanger 44, where heat is emitted to the evaporator chamber 36 under condensation of the gaseous carbon dioxide. In this phase, the gas is essentially condensed and can be conveyed through the tube 56 to a further heat exchanger 62, the task of which is to completely condense the remaining gaseous carbon dioxide in order to convey only liquid carbon dioxide back to the supply tank 18 via the tube 58, the valves 64 and 65 and the tube 60 ~~back to the supply tank 18~~.

When the distillation process ~~of destillation~~ has been finished, preparations for opening the door 12 and taking out of the clean articles of clothing follow ~~on~~. For this purpose, first the pressure in the treatment chamber 10 has to be decreased and should assume the value 1.5 bar. Thus the valve 33 will be closed while valve 55 is opened and the compressor 46 is started and can work until the pressure in the treatment chamber 10 has assumed the desired value of 1.5 bar. To make it possible to open the door 12, the pressure in the treatment chamber must be decreased further to the value 0 bar, and for this purpose a so called free-blowing takes place, which is brought about by opening a valve 39, and via a filtering device 41, conveying the remaining gaseous ~~caebon~~ carbon dioxide ~~is conveyed~~ to the ambient air.

Before the door is opened, the ~~destillate~~ distillate is taken ~~charge~~ care of, i.-e. the dirt segregated in the evaporator chamber 36. This is called dirt-blowing and implies that a valve 43 is rapidly opened and closed to press out the ~~destillate~~ distillate and at the same time minimize the amount of gaseous carbon dioxide ~~accompaning~~ accompanying the ~~destillate~~ distillate. After this ~~instant of~~ operation, the cleaning process is completed~~,~~ and the door 12 can be opened for taking out the clean articles of clothing.

~~On the eve of a following~~ Prior to a new washing process, ~~probably~~ the balance in the supply tank 18 ~~can~~ may need adjustments in respect of temperature and pressure. For this purpose, the valves 55, 64 and 65 are opened and the compressor 46 will be started and allowed to run until the pressure in the supply tank 18 assumes a suitable value, ~~in the~~ for example, 57 bar. If required, ~~also~~ the heat exchanger 62 is also activated. Afterwards, all valves are closed and the compressor 46 will be stopped.

For control of the function of the washing machine, ~~there is arranged preferable a~~ preferably, a computerized guide system~~,~~ is provided which ~~recives~~

receives information on pressure and temperature states in the treatment chamber 10, the supply tank 18 and likewise in the evaporator chamber 36 from suitable temperature and pressure sensors therein. Moreover, it is of value to be able to measure the level of liquid carbon dioxide in the supply tank 18 and in the treatment chamber 10, and to this end, suitable level gauges can be ~~arranged~~ provided. The different sensors for pressure, temperature and level are schematically shown on the drawing, but are not described in ~~details~~ detail since they are of conventional designs, and have no specific significance in ~~connnection~~ connection with the invention. The same is valid for the chosen computerized control system, which in the same way can be of any conventional kind.

As evident from the above given description of a preferred embodiment of the invention, the gaseous carbon dioxide in the described washing machine is taken care of practically completely. Due to connections between ~~those parts of the~~ different parts in the machine, ~~arranged containers holding vapour phase carbon dioxide~~ a necessary pressure balancing takes place between ~~the~~ containers holding vaporized carbon dioxide, ~~in relation to pressurizing of~~ the treatment chamber 10, and the evaporator chamber 36. The pressure balancing takes place before transferring liquid carbon dioxide from the supply tank 18 to the treatment chamber 10 and from the treatment chamber 10 to the evaporator chamber 36, respectively. In relation to the ~~destillation~~ distillation of gaseous carbon dioxide from the evaporator chamber 36, condensing takes place in the condenser or heat exchanger 44 of gaseous carbon dioxide released from the compressor 46 under raised pressure and increased heat content~~, and the heat~~. Heat given off ~~at that occasion~~ is then utilized to vaporize the liquid carbon dioxide in the evaporator chamber 36. Thus, in this way, one can dispense with specific heating arrangements for the evaporation process.

In the embodiment shown in figure 1, a separate vaporizer is arranged. To further simplify the washing machine, in a modified embodiment as shown in figure 2, the evaporator chamber 36 is excluded, and the vaporization of liquid carbon dioxide takes place directly from the treatment chamber 10. In the schematically shown example of figure 2, the vaporizer has been depicted as a box designated 80, which is ~~and~~ located beneath the treatment chamber 10~~,~~ and ~~containing~~ contains a heat exchanger 82 of a kind similar to the heat exchanger 44 in figure 1.

The function of the device shown in figure 2 is essentially the same as the one by the device according to figure 1. Owing to that, the vaporization in this

embodiment takes place directly from the treatment chamber 10 ~~in stead~~ instead of from a separate evaporator 36. Accordingly, the process steps in the embodiment according to figure 1, which ~~goes with~~ relates to the transfer of liquid carbon dioxide from the treatment chamber to the evaporator chamber, as well as some of the necessary pressure balancing moments between the evaporator chamber, the treatment chamber and the supply tank can be dispensed with.

During the condensing progress, the task in both embodiments according to figure 1 and figure 2 is to empty the treatment chamber of liquid carbon dioxide, and, at the same time, clean ~~this~~ the working fluid from impurities having been released from textiles processed in the treatment chamber. In the washing machine according to figure 2 the ~~evaporization~~ evaporation process, which ~~follow on~~ continues as the treatment phase has been concluded, in brevity takes place in the following manner.

The valves 33, 54 and 64 are opened and the compressor started so that gaseous carbon dioxide is sucked from the treatment chamber 10 through the tubes 32 and 30, the valve 33 and the tube 66. The compressor 46 delivers ~~on its compression face~~ gaseous carbon dioxide with raised pressure and increased temperature, and gas is conveyed through the tube 50, the valve 54 and the tube 52 to the heat exchanger 82, where it gives off its heat ~~and,~~ . The carbon dioxide, essentially in liquid state, is conveyed further on via the tube 56 to the heat exchanger 62, where possibly remaining gaseous carbon dioxide is transferred to liquid state. The liquid carbon dioxide is, after that, conveyed through the tube 58, the valve 64 and the tube 60 back to the supply tank 18. Thanks to the evaporator chamber, now constituting a part of the treatment chamber 10, and the heat exchanger 82, to its function as a condenser, ~~for~~ the gaseous carbon dioxide is ~~arranged~~ provided in direct connection to the treatment chamber and emits condensing heat to that, at the embodiment according to figure 2, an advantageous simplification of the washing machine is obtained. As in the embodiment of figure 1, by means of the action of the compressor 46, ~~is obtained on the whole a complete taken charge of~~ the working fluid, i.-e. carbon dioxide in liquid and gaseous state, as a whole, is completely taken care of by the compressor. Owing to that, the heat released by condensing the carbon dioxide is brought back to the process, the amount of energy needed ~~to be provided~~ from outside is restricted, and specific heating devices for evaporation of liquid carbon dioxide can be dispensed with. This also entails that every treatment phase where textiles are cleaned in liquid carbon dioxide can be followed by a ~~destilling~~ distilling phase, so that the liquid state

carbon dioxide brought back to the supply tank is always clean. This is not the case in the above mentioned publication WO-99/13148, where during the cleaning process, the liquid carbon dioxide is circulated through filtering means and the supply chamber back to the treatment chamber, and is consequently not completely cleaned like at a ~~destillation~~ distillation process. According to the invention, the problem has found its solution by way of the heat energy available in the evaporator, which has been changed up by a heat pump formed of the compressor means and the condenser means.

The invention is not restricted to the above described embodiment and in the ~~drawing shown example of embodiment~~ shown drawings, but modifications and additions can be introduced within the concept of invention as defined in the following patent claims.